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A Study of Characteristics of a Pure Fluidic Device —A Bistable Wall Attachment Amplifier with a Wedge Type Splitter and a Pentagonal Splitter—

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Abstract

To find optimum parameters of a bistable wall attachment amplifier having higher recovery pressure, an experimental research is performed using devices with two different types of splitter.

Devices with a wedge type splitter(1),(3) are not so good for obtaining higher recovery pressure because of mixing reattached flow with surrounding fluid in the output duct. For avoiding this phenomenon and getting higher recovery pressure, devices with a pentagonal splitter(2),(4) was originated so as to obtain the optimum output duct width free from the position of the splitter tip. As compared with devices with the wedge type splitter, the remarkable merits of devices with the pentagonal splitter are observed. The recovery pressure gaind by closing the output duct is in most cases less 45% of the supply for devices with the wedge type splitter, but over 45% for devices with the pentagonal splitter.

1. Introduction

For the design of a bistable wall attachment amplifier, there are many variables. In some rare cases, analytical solutions have been obtained by symplifying assumptions to pure fluidic device, but it seems very difficult to determine optimum parameters, quantitatively and theoretically. Therefore, no standardized notation has been made for switching sensitivity, input and output impedances, device efficiency, good memory, frequency response, range of control and power values, signal to noise ratios, linearity, stability under most load, higher recovery pressure and so on.

In this paper, the effects of varying main nozzle length, splitter angle, wall angle, splitter location, vent location and vent width to the recovery pressure were experimentally investigated for devices with closed output port by using devices with zero offset, and considering interconnection to other devices.

2. Experimetal Procedure

Devices used are shown in Fig.1 and dimensions are in Table 1. Devices are

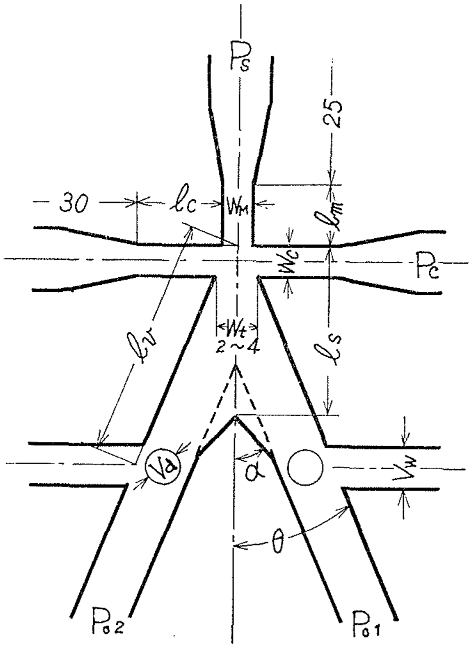


Fig. 1 Devices

P_s	Supply pressure	
P_c	Control pressure	
P_o	Output pressure	
W_M	Main Nozzle Width	2 mm
W_c	Control Nozzle Width	2 mm
W_t	Throat Width	2~4 mm
ℓ_c	Control Nozzle Length	5 mm
ℓ_v	Vent Location	20, 25, 30, 35, 40 mm
ℓ_m	Main Nozzle Length	2 mm
ℓ_s	Splitter Location	15, 17.5, 20,
V_w	Vent Width	4 mm
θ	Wall Angle	20, 23, 26, 29, 32°
α	Splitter Angle	30, 45, 60°
V_d	Vent Dia.	3.5, 4, 4.5, 5, 6 mm
h	Depth	2 mm

Table 1 Nomenclature

made of acryl resin plate and each size of devices is 5 × 70 × 80. The main nozzle is 2 mm wide and 2 mm deep, and the main nozzle length, the vent location, the vent width, the splitter angle and the splitter location are varied as shown in Table 1 for devices with the wedge type splitter. Control nozzles which have 5 mm length are of the same size as one of the main nozzle with respect to the width and the depth. For devices with the pentagonal splitter, the main nozzle length, the vent width and the output duct width are kept 4 mm by reference to the result obtained from the experiment for devices with the wedge type splitter. The main nozzle width and depth are the same as the wedge and the vent location, the splitter (penta) and the wall angle are varied, but the splitter angle is fixed 17.5mm.

There are, however, many differences between the devices with the wedge type splitter and those with the pentagonal. Even if it is considered optimum to get higher recovery pressure in case of devices with the wedge type splitter, it may be dangerous to decide parameter to be also optimum for devices with the pentagonal splitter. But, only for the purpose of reducing variables, the main nozzle length, the vent width and the output duct width are fixed as described above.

General view of apparatus is shown in Fig. 2. Air is used as working fluid.

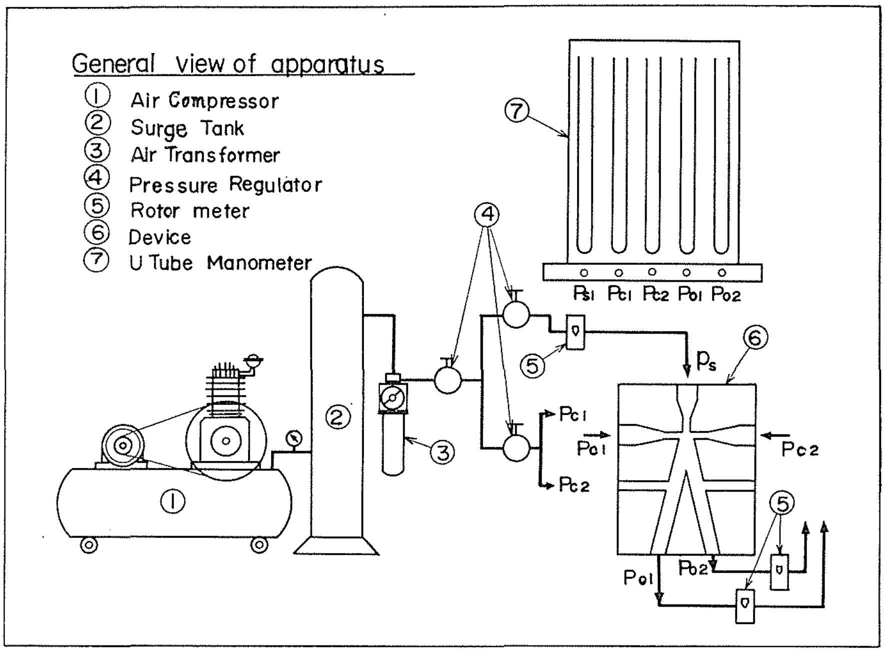


Fig. 2

The supply pressure is varied as 20, 40, 60, 80, 100 mmHg and the output pressure is measured with Aq. To measure the output flow a roter meter is used. Both control ports are always closed when there is no need of switching.

3. Experimental Result

3-1. Characteristics to Vents

When the output duct is blocked for one cause or another, it is necessary to vent for the output duct not to break memory. In proportion as load of the output increases, the output flow begines to issue not only from the output duct but also from the vent to the outside. The back pressure created in the output duct is blocked at the portion of the vent and does not affect the point of attachment. The power jet flow is then maintained stable in this position by Coanda effect. If the optimum design of vents is made, it can be thought that higher recovery pressure would be gained just before the atachment is broken.

In the design of the vent, there are two methods for making vents virtical and horizontal. As compared with making vents horizontal, to make vents virtical causes to yield many nonmemory type devices and cannot obtain higher recovery pressure. This reason is considered that vortex rotation and bubbles created at the portion of the vent cause to lose energy and to generate a pulsatory motion. The case of making vents virtical is shown in Fig. 3. It is clear that only a few memory type devices can be gained even if the vent width opens wide.

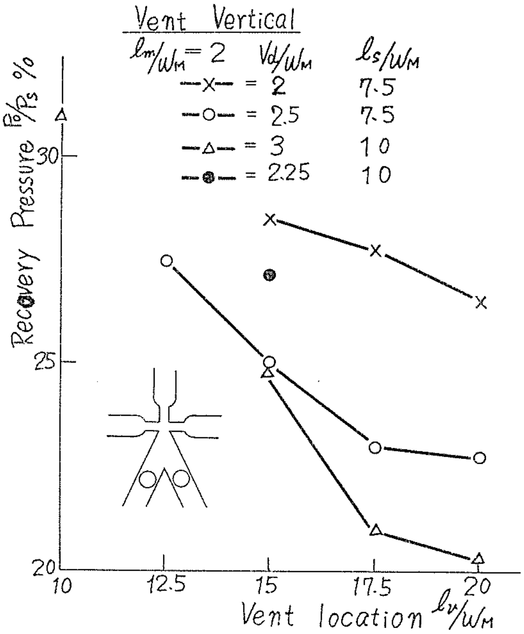


Fig. 3

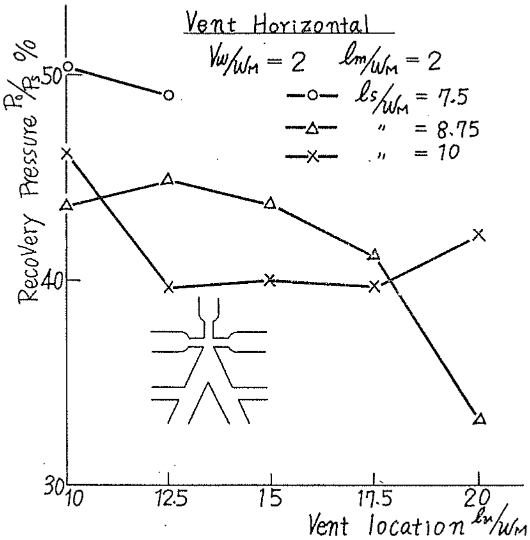


Fig. 4

On the other hands, the cases of making vents horizontal with making the splitter location parameter are shown in Fig. 4 and Fig. 5. From Fig. 4, it can be suggested that the splitter location near the power jet oriffice causes to yield nonmemory type devices, although higher recovery pressure can be obtained. The narrow interaction region is considered to induce this phenomenon. To avoid generating nonmemory devices, a means is to open the vent width wide at the sacrifice of the recovery pressure as shown in Fig. 5.

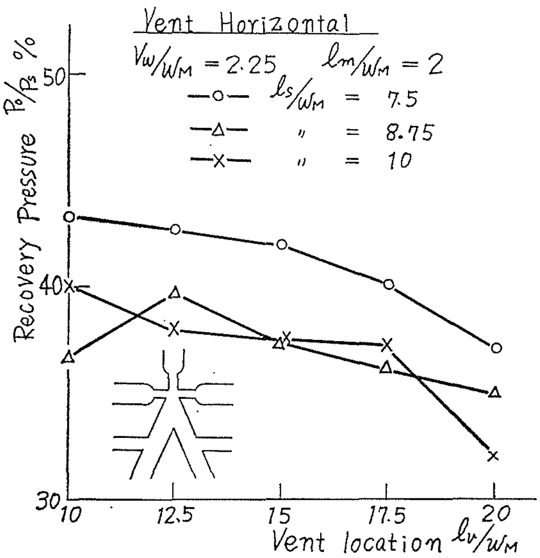


Fig. 5

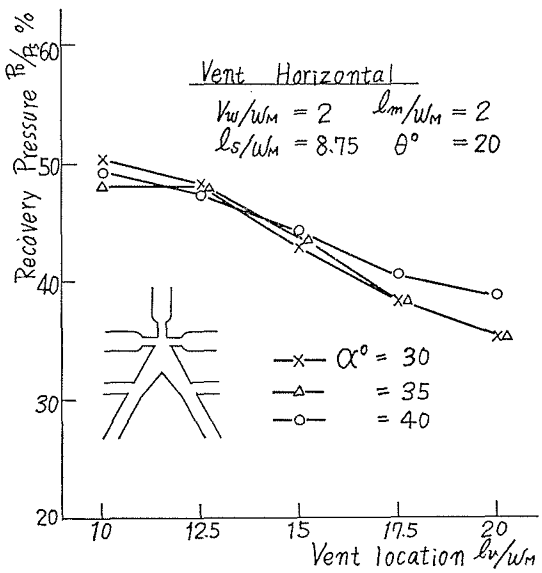


Fig. 6

Fig. 6 shows characteristics of the recovery pressure versus the vent location for devices with the pentagonal splitter with making the wall angle parameter. In this case, vents are also made horizontal. The same property is indicated to both type splitters regardless of the splitter location and the wall angle. As the vent is located far from the power jet oriffice, the recovery pressure decreases for the reason that the loss of energy dependent on the friction of wall increases. From this result, the vent is preferable to be located near the splitter location, but much care must be taken not to break the point of attachment.

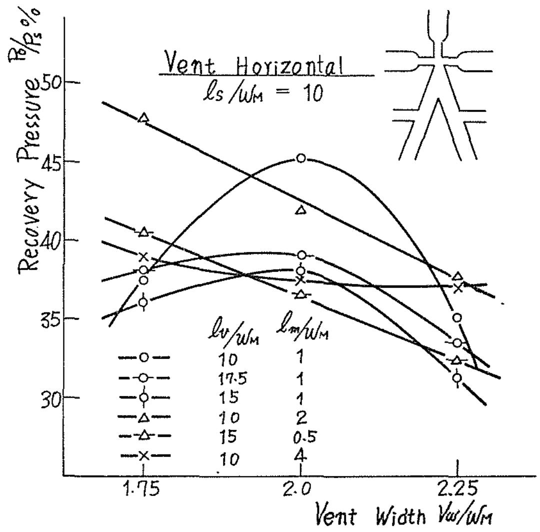


Fig. 7

As to the vent width, three cases are considered as shown in Fig. 7. From Fig. 7, it does not always follow that devices with the wide vent width have lower recovery pressure. In most cases, however, the variation of the vent width to the recovery pressure indicates the inclination of a straight line with a negative slope. The inclination of a positive and a negative quadratic curve is considered rare, but in case of $l_m/W_M = 1$,4mm vent width is considered optimum. The appropriate vent width must be determind by taking account of other parameters.

3-2. Characteristics to Angles

In case of devices with the wedge type splitter, because of using devices with zero offset and the inner and the outer wall parallel, when both splitter angle and splitter location are small, there are no changes in the output pressure in spite of the increase of the supply pressure as the output duct width becomes too narrow. From the same reason explained above, when the splitter location is made larger and the splitter angle is fixed small, an unstable phenomenon appears and memory type devices are unable to be gained. On the other hand, the same tendency is observed when the splitter angle is large and the splitter location is small. As both splitter angle and splitter location are made larger, the output duct width becomes too wide, and then this gives rise to interfere with connecting other devices and to decrease the recovery pressure.

Then, for the purpose of making a tentative basis of the splitter angle, an experiment was initially tried by making vents virtical as it was easy to do so at a seminar. This result is shown in Fig. 8. The maximum recovery pressure is obtained at 40° regardless of the supply pressure. Thereafter, the experiment was attempted to research about the splitter location smaller than 20mm by fixing the splitter angle 40°.

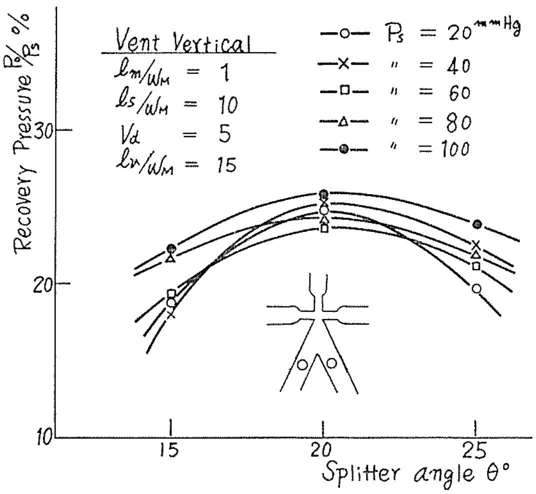


Fig. 8

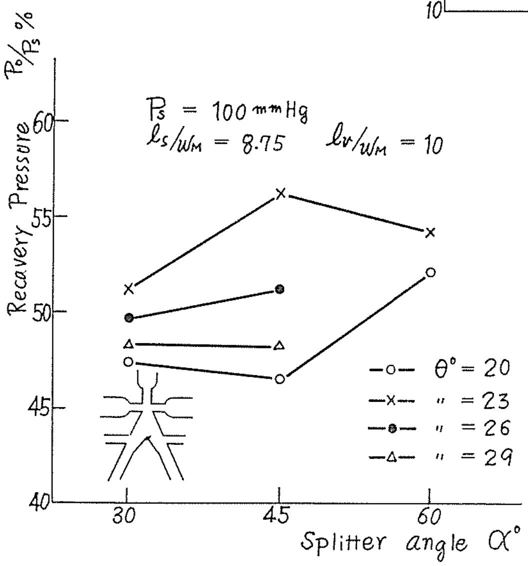
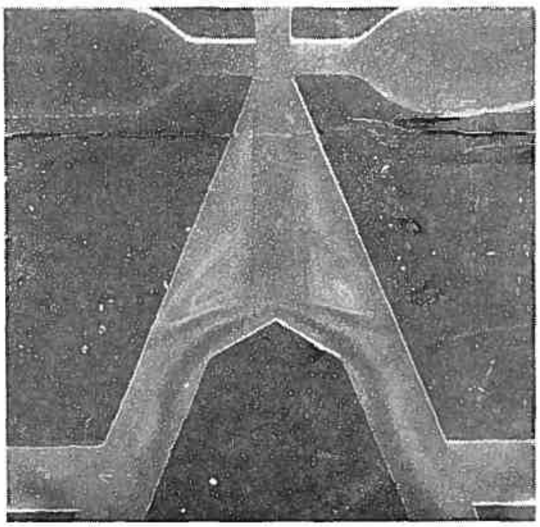


Fig. 9

As shown in Fig. 9, in cace of devices with the pentagonal splitter, there are no such troubles as in devices with the wedge type splitter, for each of the output duct width keeps constant even if the splitter angle is chaged. But when the wall angle is large and the splitter angle is small, the pentagonal splitter changes into the wedge type splitter which the inner and the outer wall are not parallel. It is then desirable to make the splitter angle large to some extent. However, when the splitter angle is too large, few memory type devices are able to be obtained. This reason is investigated by using kerosene smoke. The power jet flow comes into collision with the tip of splitter and the large vortex rotation is generated at both sides of the tip as shown in Fig. 10. Then, the power jet cannot be switched when the control flow is injected.



$l_s/W_M = 8.75 \quad l_v/W_M = 15$

$\theta = 23^\circ \quad \alpha = 60^\circ$

Fig. 10 An Example of Voltex Rotation for Nonmemory Device

Characteristics of the wall angle versus the recovery pressure is shown in Fig. 11. Memory type devices are also unable to be gained when the wall angle is large. This reason is explained as follows; when the wall spreads wide and is far from the power jet, the power jet flow is difficult to be deflected owing to the decrease of the strength of the low pressure bubble.

In this case, the splitter angle of 45° and the wall angle of 23° are considered appropriate, but it seems that there are some correlations between the splitter angle and the wall angle.

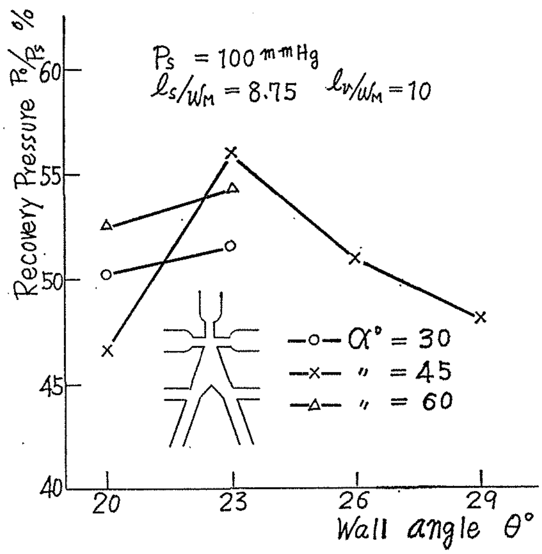


Fig. 11

3-3. Characteristics to the Main Nozzle Length.

As shown in Fig. 12、in the region of the short nozzle length, the recovery

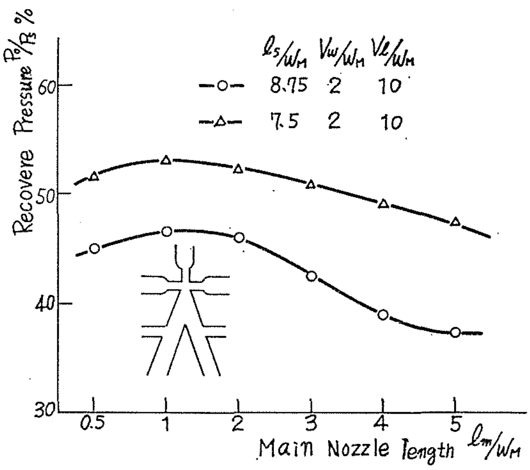


Fig. 12

pressure is not affected by the main nozzle length. It is suggested that when the nozzle length is short, the power jet flow attaches to either of the two walls as soon as fluid is issued from the power jet oriffice and the loss of energy is small, and then higher recovery pressure is gained. It is also suggested that when it is long, the loss of energy becomes lager for the reasson that the power jet flow becomes a laminar flow and comes into collision with the tip of splitter, and then the recovery pressure decreases. From these reasons, it is preferable to choice the main nozzle length short.

3-4 Characteristics to the Output Flow

For divices with the wedge type splitter, each of the output duct width is different, but as stated before, devices with the pentagonal splitter are able to keep the same those output duct width. Then the chracteristics of the static load can be gained. This is shown in Fig. 13. That the flow is zero corresponds

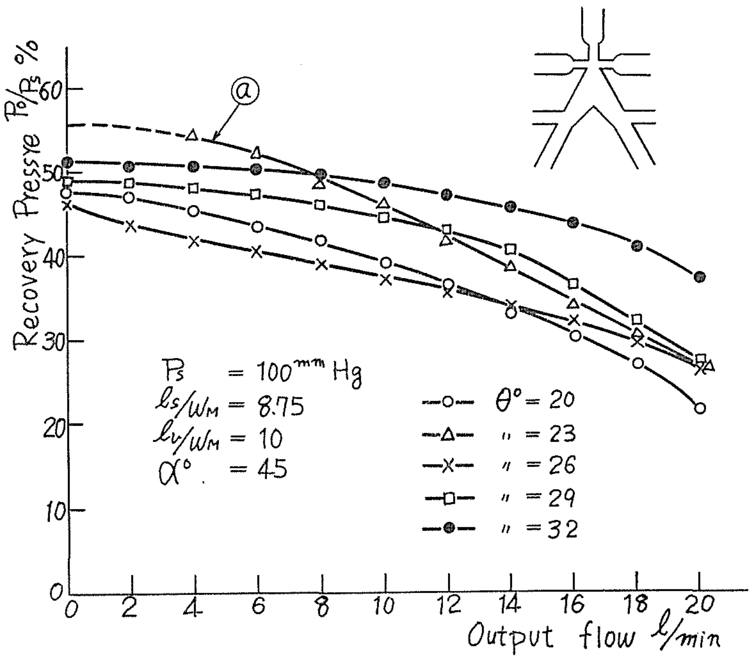


Fig. 13 Characteristics of Static Load

to give an infinite load to the output. These devices are called a load insenistive device maintaining stable memory even if the output duct from which the power jet is flowing is completely blocked. Therefore, care need not be taken to these devices for the impedance matching problem in case of multiple interconnection. This insensitivity occures because the vortex generated in a low pressure bubble maintains the same sense of rotation when the output duct is closed.

Curve A shows an example of a load sensitive device which has comparatively higher recovery pressure. This sensitivity occurs because the attachment is broken for the reason that when load come to be over some values, the static pressure in the output duct is rised and reaches gradually upstream, then, the inner pressure in the low pressure bubble increases. For this reason, the power jet flow cannot continue attaching to the wall and unstable phenomena are generated. To avoid this, it is one method to spread the vent width or the output duct. However, since the recovery pressure goes down, it is desirable to consider the impedance matching in accordance with the purpose of usage.

Subsequently, as devices are made by hand curving, an asymetric characteristic is investigated by making use of the characteristic of static load as shown in Fig. 14. From this result, the asymetric property appears obviously to devices

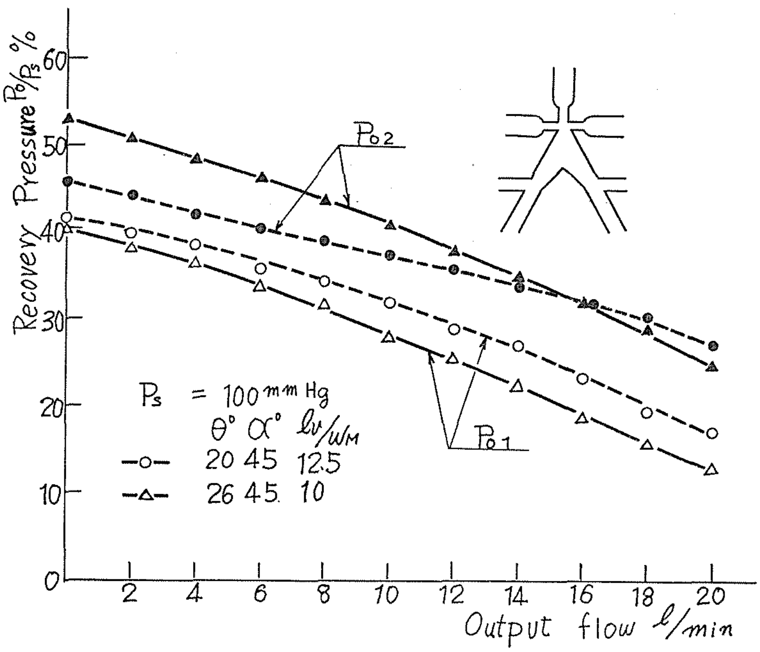


Fig. 14 Characteristics of Static Load

with higher recovery pressure. This can be considered that devices with higher recovery pressure are themselves sensitive to errors in the making and the experiment.

4. Conclusion

From the above experimental results, the merits of the pentagonal splitter can be observed as follows.

a) Higher recovery pressure is obtained.

b) The systematic experiment can be performed.

Furthermore, as for vents, to make vents virtical cause to yield less memory type devices and to get the low recovery pressure, and then it is preferable to make vents horizontal.

Acknowledgment

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References

1. J. Abe and S. Kaneko : Preprint of Japan Soc. Mech. Engrs., No.8 (1969), p.77
2. J. Abe and S. Kaneko : Preprint of Japan Soc. Mech. Engrs., No.707-1 (1970), p.77
3. K.Izawa and et al. : The First Fluidic Symp. Japan Soc. of Instrument and Control Engrs., 1966, p.15
4. M. Ota and et al. : The Third Fluidic Symp. Japan Soc. of Instrument and Control Engrs., 1968, p.55

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側壁付着型2安定素子の設計に関する研究

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側壁付着型2安定素子の設計には数多くの変数があって，その設計基準を定めるのは非常に困難である。本報では高い回復圧を得ることを目的として，スプリッタの形を楔形と駒形の2通りに変え，その各々に対してベント位置，スプリッタ角を変えて実験を行なった。

楔形のスプリッタを持つ素子は，出力端で再付着流とまわりの流体とが混り合うために一般的に高い回復圧が得られ難い。ところが駒形のスプリッタを持つ素子は，楔形のスプリッタを持つ素子が起す上記のような現象はなく，下記に示すような著しい利点がみられた。

（1）　スプリッタの位置に関係なく出力ダクト巾を一定にできるので，統一的な実験が行なえる。

（2）　回復圧が非常に高い（楔形の場合は45%以下，駒形の場合は45%以上)。

（3）　メモリタイプの素子が多く得られる。

又，ベントに関しては，3次元方向にベントを開けた場合には，製作が容易であるという利点があるが，積重ねて使用することができない，回復圧が低くメモリタイプの素子が少ないなどの欠点が多いことから，ベントは2次元方向に開けるのが望ましいということがわかった。